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The effect of regional and general anaesthesia on cerebral oxygenation in shoulder arthroscopy

Shoulder arthroscopy in the beach-chair position

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Abstract
Aim: Shoulder arthroscopy in the beach-chair position can negatively affect cerebral perfusion and oxygenation, and thus, neurocognitive function. In this study, we aimed to compare the effects of general and regional anaesthesia (GA and RA, respectively) on cerebral oxygenation in patients undergoing shoulder arthroscopy in the beach-chair position.
Material and Methods: This prospective, randomized study included 60 patients who underwent shoulder arthroscopy in the beach-chair position. Patients were divided into two groups: (1) GA (n = 30), and (2) RA using an interscalene brachial plexus block (ISB; n = 30). All patients were laid supine prior to GA or ISB (T0), and after induction of GA or ISB (T1). Next, patients were placed in the beach-chair position. The right and left cerebral oxygen saturation (NIRS-R, NIRS-L, respectively), peripheral oxygen saturation (SpO2), heart rate (HR), and mean arterial pressure (MAP) values were recorded at T0 and T1, as well as 5 (T2), 10 (T3), 20 (T4), and 30 minutes (T5) after patients were placed in the beach-chair position.
Results: Patient's clinical characteristics, initial laboratory findings, and perioperative data were similar in both groups. Compared to T0, MAP was significantly lower at T1, T2, T3, and T4 in the GA group. Tukey's HSD test indicated $p<0.05$, $p<0.0001$, $p<0.0001$, and $p<0.001$, respectively. Although NIRS-R and NIRS-L values fluctuated substantially, there were no differences between groups at any of the pre-defined time points.
Discussion: ISB in the beach-chair position may better preserve cerebral oxygenation compared to GA.

Keywords
Beach Chair Position, Cerebral Oxygenation, Interscalene Brachial Plexus Block

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Introduction

Shoulder arthroscopy is a surgical procedure that can be performed under general or regional anaesthesia (GA and RA, respectively). There are many factors that affect the decision of using GA or RA during shoulder arthroscopy which depend on the patient and physician; however, there is no consensus on the superiority of GA or RA. The preferred 'gold standard' during this procedure is an interscalene brachial plexus block (ISB), which is a form of RA [1,2]. Hypotension and bradycardia may develop secondary to anaesthesia during ISB, which are caused by stimulation of the Bezold-Jarisch reflex [1]. Hypotension can occur in patients undergoing regional as well as GA due to the vasodilator effects of anaesthetics, especially after induction [1].

Shoulder arthroscopy is performed with the patient in the beach-chair position, where the patient's head remains elevated. Hypotension is a common occurrence in these patients, which poses a risk for cerebral perfusion due to both anaesthesia and the beach-chair position [3-5]. Therefore, during shoulder arthroscopy, disruption of cerebral perfusion as a result of different mechanisms (e.g. beach-chair position, general anaesthesia, or ISB application) may affect cerebral oxygenation [6]. Permanent or transient neurological damage has been reported after shoulder surgery in the beach-chair position [7, 8]. Although the incidence rate is low (0.004%), there are reports of serious complications including vision loss, spinal cord injury, and cerebral infarction, which are associated with cerebral hypoperfusion [7-9].

Cerebral oxygenation can be measured continuously and noninvasively using near-infrared spectroscopy (NIRS). In the NIRS method, infrared light reaches the surface of the brain. Optical values of oxyhaemoglobin and deoxyhaemoglobin in the capillary bed are used for non-invasive calculation of the oxygen saturation in cerebral tissue [5]. In this method, two sensors attached to the right and left frontal regions are used to calculate the oxygen saturation of cerebral tissue, which allows for quick and early recognition of cerebral hypoperfusion despite its limitations [5].

Previous data regarding shoulder surgery in a sitting position have revealed that ISB alone is more beneficial in maintenance of the arterial pressure during the procedure compared to ISB combined with general anaesthesia [10]. A correlation between the degree of elevation in the beach chair position and the frequency of the intraoperative cerebral desaturation events, which may further lead to a neurocognitive decline, has been reported in subjects undergoing shoulder arthroscopy [11]. A head-to-head comparison of the ISB and GA in terms of hemodynamic changes and cerebral oxygenation in subjects undergoing shoulder surgery has not been performed yet. Through the evidence derived from previous studies, we hypothesized that ISB would provide a favourable hemodynamic profile and cerebral oxygenation than GA in subjects undergoing shoulder arthroscopy.

The aims of this study were to compare the effects of RA with ISB and GA on (i) cerebral oxygen saturation and (ii) heart rate (HR), mean arterial pressure (MAP), and peripheral oxygen saturation (SpO_2) in patients undergoing elective shoulder arthroscopy in the beach-chair position.

Material and Methods

Seventy-one consecutive patients, classified as American Society of Anesthesiologists (ASA) class I-III, between the ages of 18 and 70 who were scheduled for arthroscopic shoulder surgery at the Orthopaedics and Traumatology Clinic between March 2015 and January 2017 were assessed for eligibility. Written informed consents were obtained from all patients. The exclusion criteria were known coronary artery disease and/or ejection fraction below 50%, having intracranial mass, cerebrovascular disease, chronic obstructive pulmonary disease, haemoglobin values below 10 mg/dL, patients who experienced ISB failure and switched from arthroscopic to open surgery. According to the exclusion criteria, patients with known coronary artery disease (n=4), chronic obstructive pulmonary disease (n=2), haemoglobin values below 10 mg/dL (n=1) were not included in the study.

Subjects, who were eligible for the study, were randomly allocated to one of the study groups using computer-generated randomization. Randomization data were printed on charts and were kept inside opaque, sealed envelopes until the anaesthesia staff opened them in the operation theatre. The groups were as follows:

GA group: 30 patients anaesthetized using GA

RA group: 30 patients anaesthetized using ISB

All patients were premedicated with intravenous midazolam (0.03 mg/kg) at least 60 minutes before admission. Heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation (SpO_2), and end-tidal CO_2 ($EtCO_2$) monitoring were performed after admission. For cerebral oxygenation monitoring, NIRS (NONIN-Somanetics, Nonin Medical Inc. Minnesota, MN) probes were placed in the right and left frontal regions and the measured values were recorded. Measurement times are as follows:

T0= Before ISB or induction of GA in the supine position

T1= Before the beach-chair position, but after ISB or induction of GA in the supine position

T2= 5 minutes after being in the beach-chair position

T3= 10 minutes after being in the beach-chair position

T4= 20 minutes after being in the beach-chair position

T5= 30 minutes after being in the beach-chair position

In the GA group, preoxygenation was performed 3 minutes with 100% oxygen in all cases. Following the induction of GA, fentanyl (1-2 μg/kg), propofol (2-3 mg/kg), and rocuronium (0.6 mg/kg) were administered. After endotracheal intubation, mechanical ventilation parameters were adjusted to a controlled tidal volume of 7 ml/kg and $EtCO_2$ value between 30-40 mmHg. Anaesthesia was maintained with remifentanil 0.25-0.5 μg/kg/min intravenous (IV) infusion and 4-6% desflurane in a 50/50% O_2/air mixture.

In the RA group, 4 L/min O_2 support was continued with a mask, and ISB was applied with ultrasound guidance using an anterior, standard volume technique (20 ml local anaesthetic) with 10 ml 0.5% ropivacaine and 10 ml 2% lidocaine. Intermittent doses of midazolam and fentanyl were administered to patients in this group to maintain conscious sedation. The Ramsay sedation score was maintained at 2-3 on the scale, and motor and sensory block were evaluated using the modified Lovett rating scale and pinprick test, respectively [12, 13]. GA was administered to patients in cases where the block failed, and these patients were subsequently excluded from the study.

In both groups, MAP was maintained above 65 mmHg. If MAP dropped below 65mmHg, patients were treated with ephedrine (5 mg). If low MAP was accompanied by a low heart rate (below 60beats/min), patients were treated with atropine (0.5mg). Decreases of more than 20% in the NIRS-right (NIRS-R) and NIRS-left (NIRS-L) values relative to the basal value (T1) were considered critical. In these instances, the inspired oxygen rate was increased.

After GA induction and ISB application, all patients were placed in the beach-chair position and measurements were performed in 5, 10, 20 and 30th minutes.

Sample size calculation

The power calculation was based on our pilot study with first 20 patients. We used “priori t-test; the difference between the two independent means” for comparison of the difference in the MAPs of the two groups at T1 (RA group: 103 ± 15 mmHg, GA group: 96 ± 8 mmHg; alpha error: 0.05, power: 0.95 effects size: 0.9). Considering the change in MAP as a primary outcome, at least 28 patients were required in each group [14].

Statistical analysis

Data were analysed using the Statistica for Windows® Version 12 (StatSoft Inc., Tulsa, USA) computer software package. Descriptive parameters were expressed as mean ± standard deviation or median ± interquartile range. Parametric variables between groups were compared with Student’s t-tests. One-way repeated measures analysis of variances was used to assess within-group differences over time. The post-hoc Tukey’s honestly significant difference (HSD) test was used to assess group differences at individual time points. P values less than 0.05 were considered statistically significant.

Ethical Approval

This study was approved by the Ethics Committee of Manisa Celal Bayar University, Faculty of Medicine (Date: 2015-03-05, No: 20478486-112).

Table 1. mographic and clinical characteristics.

	All n=60	Group G n=30	Group R n=30	P
Age (years)	50.8±14.4	52.4±16.8	49.2±11.6	0.4*
Gender, n (%)				
Male	30 (50)	12 (40)	18 (60)	0.2**
Female	30 (50)	18 (60)	12 (40)	
BMI	27.5±4.5	26.9±4.6	28.1±4.3	0.3*
ASA class, n (%)				
I	40 (67)	21 (70)	19 (63)	0.8**
II	20 (33)	9 (30)	11 (37)	
Co-morbidity, n (%)				
Yes	23 (38)	13 (43)	10 (33)	0.6**
No	37 (62)	17 (57)	20 (67)	
Operation type, n(%)				
Bankort operation	7 (12)	4 (13)	3 (10)	0.8***
Rotator cuff repair	43 (72)	20 (67)	23 (77)	
Miscellaneous	10 (16)	6 (20)	4 (13)	
Operation side, n (%)				
Right	33 (55)	15 (50)	18 (60)	0.6*
Left	27 (45)	15 (50)	12 (40)	
In-position time (min)	89.4±25.6	87.3±24.2	91.5±27.2	0.5*
Operation time (min)	105.5±27.8	107.1±26.8	103.8±29.1	0.7*
Total fluid (mL)	1491±530	1530±516	1453±549	0.6*
Ephedrine use, n (%)	6 (10)	3 (10)	3 (10)	1.0*
Atropine use, n (%)	3 (5)	2 (7)	1 (3)	0.9**
MAB (T0) (mmHg)	101.7±9.4	102.5±7.9	101.0±10.8	0.5*
Heart rate (T0) (bpm)	79.7±12.3	80.9±14.0	78.6±10.5	0.5*
SpO2 (T0) (%)	98.3±1.4	98.6±1.3	98.0±1.5	0.1*
Mean NIRS (T0) (%)	75.2±11.8	74.4±13.8	76.0±9.6	0.6*

Data are presented as mean±standard deviation for continuous variables and as frequency for categorical variables.
Abbreviations: The American Society of Anesthesiologists, ASA; Body max index, BMI.
* Student’s t-test; ** Two-tailed Fisher’s exact test; *** Pearson chi-square test

Results

Of the 60 patients, there were 30 cases in each group. Overall, the mean age was 50.8±14.4 (Range: 19-78). Other clinical patient characteristics, initial laboratory findings, and perioperative data that may have affected the primary outcome of the study were similar between groups and are shown in Table 1. Compared to T0, MAP values were significantly lower at T1, T2, T3, and T4 in the GA group (Tukey’s HSD test, $p<0.05$, $p<0.0001$, $p<0.0001$, and $p<0.001$, respectively; Figure 1). Compared to T0, HR fluctuated considerably at all time points except for T1 in both groups; however, these changes did not reach statistical significance using post-hoc comparisons (Figure 1). SpO2 measurements were similar at all time points except for T1 where it was significantly lower in the RA compared to the GA group (97.9% vs. 99.5%, respectively; Tukey’s HSD test, $p<0.001$). Lastly, although the NIRS-R and NIRS-L values fluctuated substantially, post-hoc comparisons revealed no significant changes at any of the time points in any of the groups (Figure 2).

Discussion

In the present study, there was no significant difference in NIRS-R or NIRS-L values between the RA and GA groups. However, the NIRS-R and NIRS-L values were lower in the GA group compared to the RA group after patients were placed in the beach-chair position. Compared to baseline, patients in the GA group had significantly lower MAP values 5, 10, and 20 minutes after being placed in the beach-chair position than patients in the RA group. SpO2 levels did not decrease below 95% in 4 L/min O2 support in any of the RA cases during the operation. SpO2 values were significantly lower in the RA group just prior to the beach-chair position. After the beach-chair position was assumed, the between-group difference disappeared, which may be due to the impact of the sitting position on respiratory dynamics. There was no significant difference in HR between groups at any of the time points.

In this study, ISB was performed with an ultrasound-guided anterior approach using a standard volume technique (20 ml local anaesthetic). In the literature, unilateral diaphragmatic paralysis is observed in almost all ISB applications [15]. The resulting diaphragmatic paralysis causes a decrease in vital capacity (VC), forced expiratory volume at the first second (FEV1), and forced vital capacity (FVC), which affects pulmonary function [16, 17]. Additionally, diaphragmatic paralysis causes hypoxemia, which may affect cerebral oxygenation. Several methods have been compared in the literature to avoid

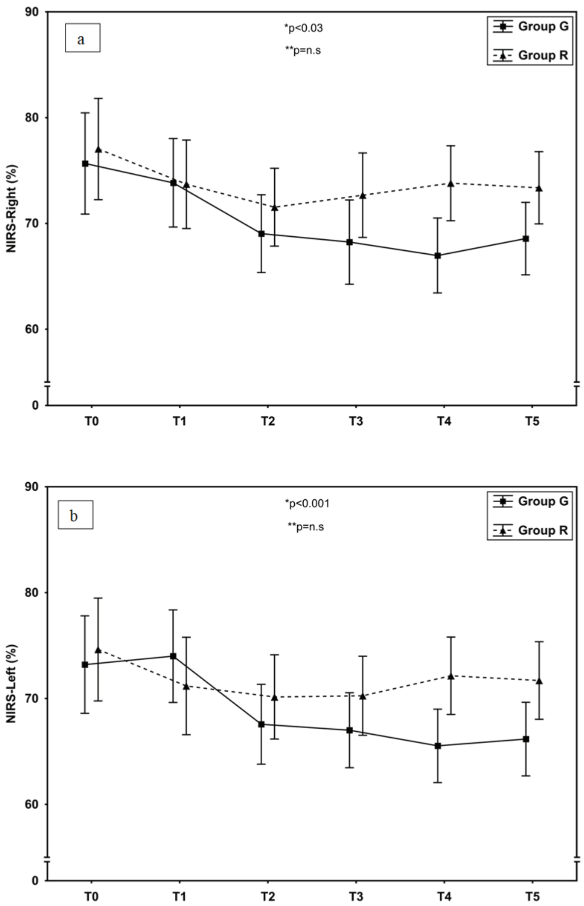

Figure 2. Changes in (a) right-sided near-infrared spectroscopy (NIRS-R) and (b) left-sided near-infrared spectroscopy (NIRS-L) as percentages over time.

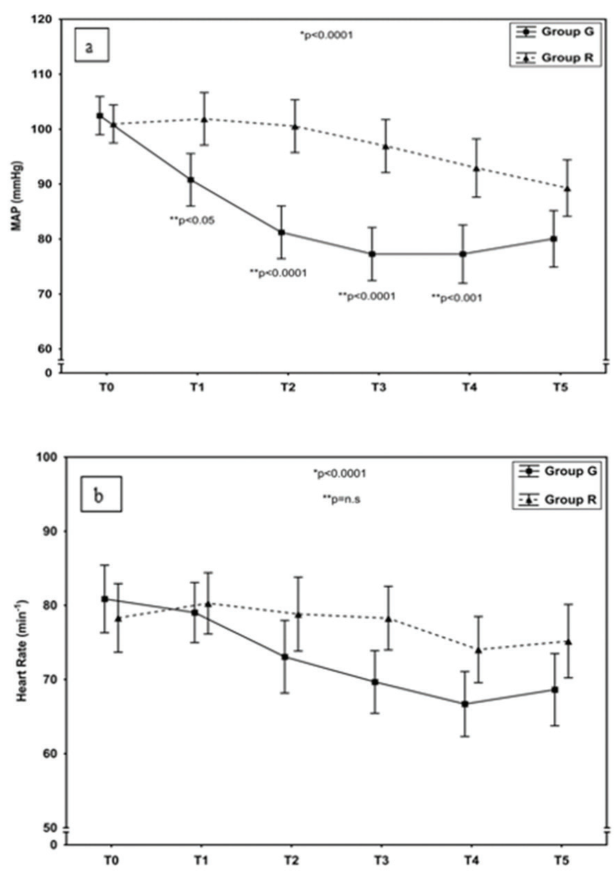

Figure 1. Changes in (a) mean arterial pressure (MAP) and (b) heart rate over time.

diaphragmatic paralysis. For example, Bergmann and colleagues compared pulmonary function using anterior and posterior approaches in ultrasound-guided ISB in patients undergoing shoulder surgery and found no difference between the two approaches [18]. In a study conducted by Ghodki and colleagues, ultrasound-guided ISB was found to be protective against diaphragmatic paralysis compared to nerve stimulation [19]. Riazi and colleagues compared the ultrasound-guided standard volume technique and the low volume technique and found that almost all patients who underwent the procedure using the standard volume technique had diaphragmatic paralysis [20]. In our study, although ISB was performed under the guidance of ultrasound, we used the standard volume technique. In the RA group, the SpO2 level immediately prior to switching to the beach-chair position was significantly lower than that of the GA group, suggesting that patients had diaphragmatic paralysis. Similarly, NIRS-L and NIRS-R values were lower in RA group compared to GA group before taking the patients to beach-chair position. On the contrary, NIRS-L and NIRS-R values were prominently higher in RA group than GA group at beach-chair position.

The hemodynamic parameters of the patients in the RA group did not show a significant decrease in cerebral oxygenation and were stable compared to the GA group. On the other hand, the MAP values of the GA group were significantly lower than the RA group and cerebral oxygenation decreased after the beach-chair position compared to the baseline value. The hemodynamic data and decrease in cerebral oxygenation after GA induction and transition to the beach-chair position are similar to previous findings [5, 21].

The application of ISB to stimulate the Bernold-Jarish reflex may result in bradycardia and hypotension. As shown in previous studies, decreased cardiac output and hypotension are positively correlated with cerebral oxygenation [5,6]. A decrease in cerebral oxygenation with ISB is to be expected given both the hemodynamic and pulmonary side effects. However, our study shows that GA results in a larger decrease in cerebral oxygenation. Therefore, ISB is the preferred method of anaesthesia for shoulder surgery in patients where cerebral oxygenation is of concern. However, care should be taken in patients with impaired pulmonary function, such as pulmonary diseases and obesity [9]. Janssen and colleagues found no differences in hemodynamic data between GA alone, and GA combined with ISB.1 Since the combination of GA and ISB did not increase hemodynamic side effects relative to GA alone, this suggests that the combination did not cause a decrease in cerebral oxygenation. However, no studies have compared the use of ISB alone to GA for anaesthesia.

In our study, MAP values significantly decreased after GA induction, as well as after the beach-chair position. While the effect of hemodynamic changes in the beach-chair position on cerebral oxygenation was significant in the GA group, this was not observed in the RA group. GA induction often results in a decrease in MAP due to cardiovascular effects, which becomes more pronounced when patients are placed in the beach-chair position.

One limitation of the present study is that the measurements performed by the NIRS method may be influenced by several factors, including the location of the sensors, arterial and venous vascular density around the NIRS sensors, presence of arterio-venous shunts or oedema at sites where the sensors have been placed. Second, the absence of any significant difference in NIRS values between the groups may have been influenced by the enrolment of healthy individuals without severe comorbidities. Therefore, these results cannot be generalized extensively to all subjects undergoing arthroscopic shoulder surgery. Future studies in subjects with atherosclerosis, intracranial mass, cerebrovascular disease, chronic obstructive pulmonary disease, and heart failure are required to address the role of ISB in subjects with comorbid conditions.

Conclusion

In the beach-chair position, ISB did not cause a significant decrease in cerebral oxygenation. Although it did not reach statistical significance, this study showed that cerebral oxygenation was worse in patients who were placed in the beach-chair position under GA than in subjects receiving RA with ISB.

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Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or compareable ethical standards.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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